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Effectiveness of Mobile Applications for Self-Monitoring of Blood Glucose in Older Adults with Type 2 Diabetes: A Systematic Review

Eficacia de las aplicaciones móviles para el autocontrol de la glucemia en adultos mayores con diabetes tipo 2: una revisión sistemática

Okti Sri Purwanti[1ab]*, Artika Nurrahima[2ac], Dwi Retnaningsih[3ad], Susi Wahyuning Asih[4ae], Nursalam Nursalam[5a]

SUMMARY

Introduction: *Type 2 diabetes mellitus (T2DM) is a chronic disease experienced by many older adults and requires regular blood glucose monitoring to avoid complications. Mobile applications for self-monitoring of blood glucose (SMG) are an innovative solution for supporting self-management of T2DM patients, especially among the elderly. This work aimed to evaluate the effectiveness of a mobile application for self-monitoring of blood glucose on clinical outcomes, behavioral changes, and user experience in older individuals with type 2 diabetes mellitus (T2DM).*
Methods: *A systematic review was conducted in accordance with the PRISMA guidelines. A literature search was conducted in four major databases: Scopus, PubMed, ProQuest, and EBSCO CINAHL, using the keywords: "self-monitoring," "blood glucose control," "diabetes," and "application." Studies that met the inclusion criteria were experimental or observational and involved elderly participants who used a mobile application for blood glucose monitoring.*
Results: *A total of 25 selected articles were analyzed narratively. Most studies have shown that using mobile apps increases the frequency of blood glucose monitoring, lowers HbA1c levels, and enhances patient satisfaction and engagement. Some apps also supported self-education and digital record keeping integrated with health services. However, challenges persist due to technical limitations and a lack of digital literacy among some elderly users.*
Conclusion: *Mobile apps have been proven to be practical tools for self-monitoring of blood glucose in older adults with type 2 diabetes mellitus (T2DM), from both clinical and behavioral perspectives. The development of elderly-friendly applications integrated with health services is crucial for supporting sustainable diabetes management.*

Keywords: *Blood Glucose, elderly, diabetes mellitus type 2, mobile application, self-monitoring.*

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ORCID: 0000-0002- 6964 -6884[1]
ORCID: 0000-0002- 2653 -2959[2]
ORCID: 0000-0002- 2649 -4809[3]
ORCID: 0000-0002- 6884 -2795[4]
ORCID: 0000-0001- 9052 -6983[5]

[a] Doctoral Programme, Faculty of Nursing, Universitas Airlangga.
[b] Nursing Program, Faculty of Health Science, Universitas Muhammadiyah Surakarta.
[c] Nursing Department, Faculty of Medicine, Diponegoro University
[d] Nursing Study Program, Universitas Widya Husada Semarang.
[e] Faculty of Health Nursing, Muhammadiyah University of Jember.

*Corresponding Author: Okti Sri Purwanti
E-mail: okti.sri.purwanti-2023@fkp.unair.ac.id

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RESUMEN

Introducción: *La diabetes mellitus tipo 2 (DM2) es una enfermedad crónica que afecta a muchos adultos mayores y requiere un control regular de la glucemia para evitar complicaciones. Las aplicaciones móviles como herramienta para el autocontrol de la glucemia (SMG) constituyen una solución innovadora para apoyar la autogestión de los pacientes con DM2, especialmente en la tercera edad. El objetivo fue evaluar la eficacia del uso de una aplicación móvil para el autocontrol de la glucemia en los resultados clínicos, los cambios de comportamiento y la experiencia del usuario en personas mayores con DM2.*

Métodos: *Se realizó una revisión sistemática siguiendo las directrices PRISMA. Se realizó una búsqueda bibliográfica en cuatro bases de datos principales: Scopus, PubMed, ProQuest y EBSCO CINAHL, utilizando las palabras clave: "autocontrol", "control de la glucemia", "diabetes" y "aplicación". Los estudios que cumplieron los criterios de inclusión fueron experimentales u observacionales, con participantes mayores que utilizaron una aplicación móvil para el control de la glucemia.*

Resultados: *Se analizaron narrativamente 25 artículos seleccionados. La mayoría de los estudios demostraron que el uso de aplicaciones móviles aumentó la frecuencia de la monitorización de la glucemia, redujo los niveles de HbA1c y mejoró la satisfacción y la participación de los pacientes. Algunas aplicaciones también facilitaron la autoformación y el registro digital de datos, integrados con los servicios de salud. Sin embargo, persisten desafíos relacionados con las limitaciones técnicas y con la falta de alfabetización digital entre algunos usuarios de edad avanzada.*

Conclusión: *Se ha demostrado que las aplicaciones móviles son eficaces como herramientas para la automonitorización de la glucemia en adultos mayores con DMT2, tanto desde el punto de vista clínico como desde el conductual. El desarrollo de aplicaciones adaptadas a las personas mayores e integradas con los servicios de salud es importante para promover un control sostenible de la diabetes.*

Palabras clave: *Glucemia, adultos mayores, diabetes mellitus tipo 2, aplicación móvil, automonitorización.*

INTRODUCTION

Diabetes mellitus is a global health problem that is not only increasing in prevalence but also shifting toward populations least equipped to manage it, making it one of the most urgent global health challenges of our time. This disease is characterized by impaired glucose metabolism, leading to prolonged hyperglycemia (chronic hyperglycemia) (1). This condition occurs due to an absolute or relative deficiency of insulin or the body's inability to utilize insulin effectively. Persistent hyperglycemia can cause various acute and chronic complications that impact patients' quality of life, increase morbidity, and even cause mortality. Therefore, controlling blood glucose levels is the primary focus in the management of diabetes mellitus (2).

The primary challenge in diabetes management is the difficulty patients face in consistently maintaining blood glucose levels within normal limits. Diabetes management requires active patient involvement through continuous self-monitoring, lifestyle changes such as a healthy diet and regular physical activity, and adherence to a pharmacological therapy regimen. However, in practice, most patients face various obstacles in routinely monitoring their blood glucose. These obstacles can include limited access to testing equipment, lack of knowledge about the importance of monitoring, low health literacy, and psychological factors such as unstable motivation. This situation means that diabetes control is still far from optimal and increases the risk of long-term complications.

The global burden of type 2 diabetes mellitus (T2DM) has escalated dramatically. According to the International Diabetes Federation (IDF), over 537 million adults were living with diabetes in 2021, and this number is projected to rise to 643 million by 2030, with older adults representing a significant proportion of these cases (IDF, 2021). In low- and middle-income countries, such as Indonesia, national health surveys report a steadily increasing prevalence among individuals aged 55 years and older, signaling a public health priority (3). Older patients often struggle with routine self-monitoring of blood glucose (SMBG) due to visual limitations, physical frailty, cognitive decline, or technological illiteracy, which can reduce adherence and the effectiveness of treatment (4).

The management of diabetes mellitus requires active patient involvement through routine self-monitoring of blood glucose, adherence to pharmacological therapy, and the implementation of sustainable lifestyle changes (5). However, various obstacles, including limited access to monitoring devices, low health literacy, and low

patient motivation, often result in suboptimal glycemic control. This condition increases the risk of acute and chronic complications, thereby adding to the burden of morbidity, mortality, and health costs.

Based on current developments, digital transformation in healthcare presents new opportunities to support the management of chronic diseases, including diabetes. Over the past decade, digital health technologies, particularly mobile health (mHealth) applications, have emerged as innovative solutions to overcome the limitations of conventional blood glucosemonitoring. These applications enable patients to track their blood glucose levels, receive medication reminders, access health education resources, and share data with healthcare professionals. Several studies, including randomized controlled trials and cohort studies, have demonstrated that mHealth applications can significantly lower HbA1c levels and increase patient satisfaction, particularly among older adults at higher risk of diabetes complications (6).

The integration of mobile health (mHealth) into diabetes management aligns with the global shift toward more personalized, measurable, and data-driven healthcare systems. Blood glucose monitoring applications are now increasingly sophisticated, thanks to cloud-based systems, wearable devices, and connectivity with electronic medical records (EMR) (7). This combination enables real-time feedback and remote monitoring, thereby increasing patient engagement while supporting clinical decision-making by healthcare professionals (8).

Current developments in digital technology show promising potential, but variations in usability, accessibility, and sustained effectiveness remain a challenge. The effectiveness of mobile applications is influenced by the features offered, interface design, and user characteristics, including age and digital literacy level. This is of particular concern for older adults with diabetes, who often face barriers to using digital health technologies. With the increasing need for more practical, adaptive, and user-friendly diabetes interventions, a comprehensive synthesis of evidence on the effectiveness of blood glucose monitoring applications is needed.

Therefore, this systematic review aimed to evaluate the effectiveness of mobile applications for self-monitoring of blood glucose in older adults with type 2 diabetes, with a focus on clinical outcomes, self-care behaviors, and patient experiences.

METHODS

Study Design

A systematic review research design was chosen to answer the research question: "What are the forms of information system-based *self-monitoring blood glucose (SMBG)* that affect blood glucose levels in patients with diabetes mellitus?" This literature review design was appropriate because the sources ranged from journal articles to official websites. A systematic review identifies in-depth, comprehensive literature from various sources and employs diverse research methods related to the research topic.

Search Methods

Articles were searched through PubMed, Scopus, Proquest, and Ebsco CINAHL databases using the keyword combination "Self-monitoring," "blood glucose control," "diabetes," "application" OR (Self-monitoring) AND (blood glucose control) AND (diabetes) AND (application). All researchers conducted independent database searches, focusing on selecting literature that discussed interventions as self-monitoring efforts to control blood glucose levels in patients with diabetes mellitus. Additionally, the article screening process was conducted using Rayyan. Ai, an artificial intelligence-based web platform designed to support systematic reviews. On this platform, each researcher independently screened titles and abstracts in a blinded mode to minimize selection bias. Articles were then categorized as "include," "exclude," or "maybe," and the system automatically flagged differences in assessment. Conflicts that arose were further discussed and resolved through consensus among the research team to ensure transparency and accuracy in the study selection process.

Inclusion and exclusion criteria

The inclusion criteria included reviewing all types of articles, except full-text systematic reviews, published in reputable journals. Articles included subjects with diabetes mellitus, interventions were innovations or developments in information systems, and research outcomes focused on blood glucose monitoring applications. Exclusion criteria included non-diabetes patient subjects, studies not investigating information system-based *self-monitoring blood glucose (*SMBG) interventions, articles written in languages other than English, articles with review design, letters to the editor, book chapters, and incomplete articles.

Data extraction

The first author facilitated the article screening process using Rayyan.Ai to select articles in accordance with the mutually agreed-upon, predetermined inclusion and exclusion criteria. After duplicate articles were removed, the four researchers divided into groups to search their respective databases for articles using the agreed-upon keywords. After retrieving various articles from the database using the keywords, the first author led a discussion to review the article titles and abstracts against the predetermined eligibility criteria. Next, data extraction and synthesis were performed by considering: 1. author and year, 2. research design, 3. sample, 4. variables, 5. instruments, 6. interventions, 7. analysis, 8. Results.

RESULTS

Selection Process (Prism)

The literature selection process followed the PRISMA 2020 flow as shown in Figure 1. From a total of 13 757 articles obtained from the predetermined database, 309 duplicate articles were removed. Next, an initial screening was conducted, resulting in the exclusion of 3,881 articles that did not meet the inclusion criteria. At the eligibility assessment stage, 18 articles were eliminated due to variable incompatibility. The final selection stage excluded an additional 2 813 articles that did not meet the inclusion criteria for participants, interventions, outcomes, or study types. The final selection yielded 27 eligible articles for further analysis (Figure 1).

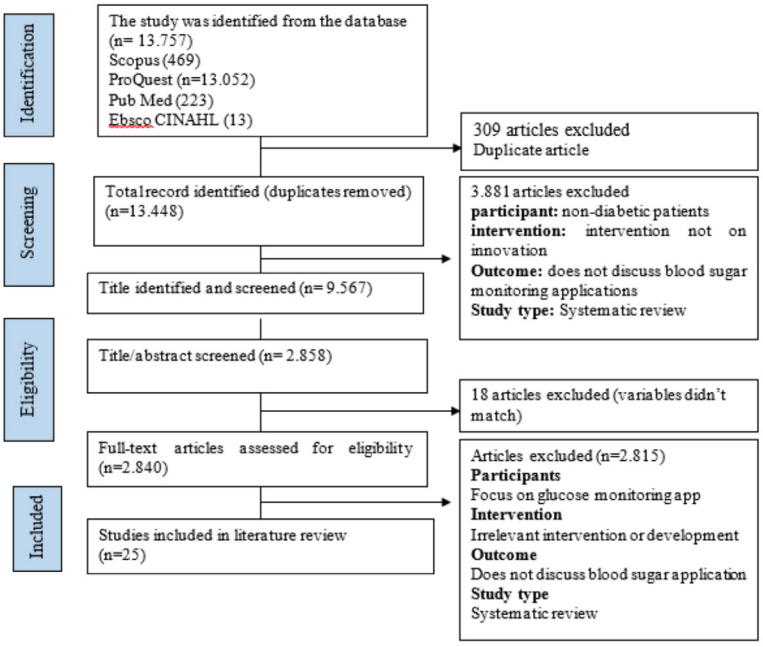

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA).

Quality Assessment

Risk of bias assessment was conducted independently by the first and second authors using the Critical Appraisal Checklist from the Joanna Briggs Institute (JBI). Discrepancies in the assessment were resolved through discussion with the third or fourth author until consensus was reached. This checklist was selected to assess the quality of the methodology, potential bias, and appropriateness of the study in relation to the research objectives. Based on the assessment results, all selected articles demonstrated high quality and a low risk of bias, with at least 10 "yes" answers for randomized controlled trials (10) and more than 7 for cohort studies (11). The authors chose this Critical Appraisal Checklist because it assesses methodological quality, identifies bias, evaluates study limitations and strengths, and assesses conformity with research objectives (Tables 1 through 4) (12).

Article analysis

Based on the 25 articles analyzed, this study used the PICO (Population, Intervention, Comparison, Outcome) approach to identify information system-based *self-monitoring blood glucose* (SMBG) interventions that affect blood glucose levels in patients with diabetes mellitus (Table 5).

Table 1. JBI Critical Appraisal Checklist for Randomized Controlled Trials.

Number of Articles	Question													Total	Score (%)	Criteria quality
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13			
1	1	1	1	1	1	1	1	1	0	1	1	1	1	12	92	High
6	1	1	1	1	0	1	1	1	1	1	1	1	1	12	92	High
7	1	1	1	1	1	1	1	0	1	1	1	1	1	11	84	High
10	1	1	1	1	1	1	1	1	1	1	1	1	1	13	100	High
11	1	1	1	1	1	1	1	1	0	1	0	1	1	11	84	High
12	1	1	1	1	1	1	1	1	1	1	1	0	1	12	92	High
13	1	1	1	1	1	1	1	1	0	1	0	1	1	11	84	High
14	1	1	1	1	1	1	1	1	1	1	1	1	1	13	100	High
15	1	1	1	1	1	1	1	1	0	1	1	1	1	12	92	High
16	1	1	1	1	1	0	0	1	0	1	1	1	1	10	76	High
17	1	1	1	1	0	1	0	1	1	1	1	1	1	11	84	High
18	1	1	1	1	1	1	1	1	1	1	1	1	1	13	100	High
22	1	1	1	1	1	1	1	1	1	0	0	1	1	11	84	High
23	1	1	1	1	1	1	1	1	1	0	1	1	1	12	92	High
24	1	1	1	1	1	1	1	1	1	1	1	1	1	13	100	High
25	1	1	1	1	1	1	1	1	1	1	1	1	1	13	100	High
27	1	1	1	1	1	1	1	1	1	0	1	1	1	12	92	High

Q1: Was proper randomization used for the assignment of participants to treatment groups?; Q2: Was allocation to treatment groups concealed?; Q3: Were treatment groups similar at baseline?; Q4: Were participants blind to treatment assignment?Q5: Were those delivering treatment blind to treatment assignment?; Q6: Were outcome assessors blind to treatment assignment?; Q7: Were treatment groups treated identically, other than the intervention of interest?; Q8: Was follow-up complete, and if not, were differences between groups in terms of their follow-up adequately described and analyzed?Q9: Were participants analyzed in the groups to which they were randomized?; Q10: Were outcomes measured in the same way for treatment groups?; Q11: Were outcomes measured reliably?; Q12: Was an appropriate statistical analysis used?Q13: Was the trial design appropriate, and were any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Table 2. JBI Critical Appraisal Checklist for Cohort Study.

Number of Articles	Questions											Total	Score (%)	Criteria quality
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11			
4	1	1	1	1	1	1	1	1	1	1	1	11	100	High
19	1	1	1	1	1	1	1	1	0	1	1	10	91	High
20	1	1	1	1	1	1	1	1	1	1	1	11	100	High

Q1: Were the two groups similar and recruited from the same population?Q2: Were the exposures measured similarly to assign people to both the exposed and unexposed groups?Q3: Was the exposure measured validly and reliably?Q4: Were confounding factors identified?Q5: Were strategies to deal with confounding factors stated?; Q6: Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?; Q7: Were the outcomes measured validly and reliably?; Q8: Was the follow-up time reported sufficient to be long enough for outcomes to occur?; Q9: Was follow-up complete, and if not, were the reasons for the loss of follow-up described and explored?Q10: Were strategies to address incomplete follow-up utilized?; Q11: Was an appropriate statistical analysis used?

Table 3. JBI Critical Appraisal Checklist for Cross-Sectional Study

Number of Articles	Questions								Total	Score (%)	Criteria quality
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8			
2	1	1	1	1	1	1	1	1	8	100	High
3	1	1	1	1	1	1	1	1	8	100	High
9	1	1	1	1	1	1	1	1	8	100	High
26	1	1	1	1	1	1	1	1	8	100	High

Q1: Were the criteria for inclusion in the sample clearly defined?Q2: Were the study subjects and the setting described in detail?Q3: Was the exposure measured validly and reliably?Q4: Were objective, standard criteria used for measurement of the condition?; Q5: Were confounding factors identified?Q6: Were strategies to deal with confounding factors stated?; Q7: Were the outcomes measured validly and reliably?; Q8: Was an appropriate statistical analysis used?

Table 4. JBI Critical Appraisal Checklist Qualitative Research (Delphi Consensus Study & Exploratory Study).

Number of Articles	Questions										Total	Score (%)	Criteria quality
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
5	1	1	1	1	1	1	1	1	1	1	10	100	High
8	1	1	1	1	1	1	1	1	1	1	10	100	High
21	1	1	1	1	1	1	1	1	0	1	9	90	High

Q1: Congruity between the stated philosophical perspective and the research methodology; Q2: Congruity between the research methodology and the research question or objectives; Q3: Congruity between the research methodology and the methods used to collect data; Q4: Congruity between the research methodology and the representation and analysis of data; Q5: There is congruence between the research methodology and the interpretation of results; Q6: Locating the researcher culturally or theoretically; Q7: Influence of the researcher on the research, and vice-versa, is addressed; Q8: Representation of participants and their voices; Q9: Ethical approval by an appropriate body; Q10: Relationship of conclusions to analysis, or interpretation of the data.

Table 5. Article Analysis.

No.	Research Title & Citation	Journal Name	Research Method	Research Result
1.	Efficacy of a smartphone application for helping individuals with type 2 diabetes mellitus manage their blood glucose: a protocol for factorial design trial (Tang et al., 2023) (13)	Trials Journal	**Design:** Randomized Control Trial **Sample:** patients with type 2 diabetes mellitus aged > 18 years. **Variables:** the primary variable is change in HbA1c levels, secondary variables are blood glucose monitoring, body mass index, blood pressure, diabetes knowledge, health beliefs, self-management behaviors, and satisfaction with the smartphone app **Instruments:** Various questionnaires will be used, including the Diabetes Knowledge Questionnaire (DKN) and Health Belief Questionnaire (HBQ), **Analysis:** Data will be analyzed using SPSS 23.0, with statistical methods including chi-squared test, analysis of variance.	This study aims to determine the effectiveness of smartphone apps in improving glycemic management among individuals with type 2 diabetes mellitus (T2DM), with the findings expected to inform future app development.
2.	Internet of Things enabled open source assisted real-time blood glucose monitoring framework (Abubeker et al., 2024) (38)	Nature Journal	**Design:** Comparative Study, **Sample:** Three groups categorized by age, diabetes status, and HbA1c level, providing a diverse representation of the diabetes population. **Variables:** The primary variables are blood glucose levels, HbA1c levels, and demographic factors such as age and diabetes status, which are crucial for understanding the effectiveness of the monitoring system. **Instruments:** The primary instrument is the IgM gadget, which utilizes a Red Near-Infrared (R-NIR) sensor. **Analysis:** The analysis compared the accuracy of the IgM gadget with laboratory tests, focusing on signal quality and streaming capabilities, especially for ICU and isolated elderly patients.	The IgM gadget achieved high accuracy rates of 98.82% after fasting and 98.04% after a meal, demonstrating its potential to manage diabetes and improve the quality of life for the elderly.
3.	Effects of Digitization of Blood Glucose Records Using a Mobile App and the Cloud System on Outpatient Management of Diabetes: A Single-Armed Prospective--Study (Handa et al., 2024) (14)	JMIR Publication	**Design:** Prospective Cohort Study **Sample:** A total of 48 diabetic elderly (type 1 and type 2 diabetes). **Variables:** The primary outcome variable was the change in glycated hemoglobin (HbA1c) levels. Secondary variables included frequency of self-monitoring of blood glucose (SMBG) and elderly satisfaction as measured by the Diabetes Treatment Satisfaction Questionnaire (DTSQ). **Instruments:** The study utilized the Smart e-SMBG mobile app for data collection, along with the DTSQ to assess elderly satisfaction. **Analysis:** Statistical analysis was conducted to compare changes in HbA1c levels and SMBG frequency at 12 and 24 weeks, with significance levels reported.	The study found no significant change in overall HbA1c levels, but there was a significant increase in the frequency of daily SMBG. In addition, the satisfaction scores of older adults increased significantly after using the system.
4.	Type 2 diabetes in Latin America: recommendations on the flash glucose monitoring system (Krakauer et al., 2024) (39)	Diabetology and Metabolic Syndrome Journal	**Design:** Delphi Consensus Study, **Sample:** Panel of 15 physicians (endocrinologists and internal medicine physicians). **Variables:** Key variables included the effectiveness of FcGM in managing T2DM, the elderly profile, treatment goals, and the frequency of glucose monitoring. Instrument: A 17-item instrument was developed to measure expert perceptions, utilizing a Likert scale and SWOT analysis to evaluate FCGMs' strengths, weaknesses, opportunities, and threats. **Analysis:** Analysis involved a degree of consensus, with a target of at least 80% agreement among participants on recommendations.	The study concluded that FCGM is recommended for older adults with T2DM, with individualized metrics for monitoring and a median of 6 to 10 glucose scans per day based on treatment type.
5.	Use of Continuous Glucose Monitoring in Older Adults: A Review of Benefits, Challenges, and Future Directions (Prasad-Reddy et al., 2022) (15)	Touch Endocrinology Journal	**Design:** Randomized Controlled Trial (RCT) **Sample:** 116 older adults (aged >60 years) with type 1 and 2 diabetes using insulin. **Variables:** Use of CGM vs. manual monitoring, HbA1c, and time in hypoglycemia state. **Instruments:** CGM and satisfaction survey. **Analysis:** Paired t-test to compare changes in HbA1c.	CGM use showed significant reductions in HbA1c and glucose variability, as well as a decrease in time spent in hypoglycemia. Older adults reported positive experiences with the CGM.

Continued in pag. S170…

…continuation Table 5. Article Analysis.

No.	Research Title & Citation	Journal Name	Research Method	Research Result
6.	A telemedicine-based approach with real-time transmission of blood glucose data improves metabolic control in insulin-treated diabetes: the DIAMONDS randomized clinical trial (Di Molfetta et al., 2022) (7)	Springer Nature	**Design:** Randomized Controlled Trial (RCT) **Sample:** 123 diabetic older adults using insulin. **Variables:** Telemedicine intervention vs. standard control, change in HbA1c, frequency of hypoglycemia. **Instruments:** A glucometer connected to an app for the real-time transmission of blood glucose data. **Analysis:** Paired t-test and ANOVA for comparison of time and frequency of hypoglycemia.	The telemedicine intervention group showed improved metabolic control, with a significant reduction in HbA1c and fewer hypoglycemic episodes.
7.	Seamless recording of glucometer measurements among older experienced diabetic patients - A study of perception and usability (Rasche et al., 2018) (16)	Plos ONE	**Design:** Exploratory Study **Sample.** The sample consisted of 12 elderly individuals with long-term diabetes (mean age, 66.5 years). Key variables included the usability of the IBG-Star glucometer, users' attitudes towards the device, and barriers to its implementation in routine care. **Instruments:** Data collection involved questionnaires, usability tasks, and structured interviews. The Post-Study System Usability Questionnaire was used to assess the glucometer's usability. **Analysis:** Data were analyzed using SPSS statistical software, version 22, to assess usability and user feedback.	The study found that IBG-Star was generally easy to use, with participants appreciating the automated data storage. However, barriers such as interoperability with medical systems were identified.
8.	Assessing quality of glycemic control: Hypo- and hyperglycemic, and glycemic variability using mobile monitoring of blood glucose system (Guo, 2020) (28)	Sage JOURNAL	**Design:** Multi-method Sample: 30 older adults with type 2 diabetes (aged 23-76) **Variables:** Mobile diabetes self-care system (DSCS) Glycemic variability **Instrument:** Mobile diabetes self-care system (DSCS)	The analytic results, showing a downward trend in glycemic fluctuations week by week, imply that glycemic status is moving towards greater stability after short-term use of the DSCS system.
9.	Automated Personalized Self-Care Program for Patients with Type 2 Diabetes Mellitus: A Pilot Trial (Park et al., 2024) (2)	Asian Nursing Research	**Design:** parallel randomized pilot trial with qualitative interviews. **Sample:** 32 elderly with type 2 diabetes, aged 40 to 69 years (intervention n: 19, control n: 13). **Variables:** Automated Personalized Self-Care (APSC) app, diabetes self-efficacy, exercise, HbA1c levels, and depressive symptoms. **Instruments:** Quantitative: Automated Personalized Self-Care (APSC) app, blood glucose, the Korean version of the Center for Epidemiological Studies-Depression Scale (CES-D), the Korean version of the SF-12v2 Health Survey. Qualitative: Key question: "How was your experience participating in the program for the past three months?" "What challenges did you encounter while participating in the program?" "What efforts did you make to stay engaged in the program?" "What changes have you noticed during your participation in the program?" and "What were your thoughts and feelings when you participated well or did not participate well in the program?" Analysis: Quantitative: t-test and Mann-Whitney U test, Qualitative: inductive content analysis	Mobile DSCS has good benefits for establishing the GV picture. The mean weekly frequency of self-care activities included exercise (4.61), diet (5.77), glucose monitoring (4.90), and medication (5.62). HbA1c decreased significantly in the intervention group (8.3% to 7.4%) compared to controls (8.2% to 8.0%), with no significant differences in BG, LDL-C, depression, and quality of life. A total of 81.3% of participants engaged in self-care activities more than 4 times per week. The app usability score reached the lower limit of acceptability (66.25). Qualitatively, participants suggested dietary variations and adjustments to exercise goals. Errors in the app decreased trust, so immediate technical improvements are needed.
10.	Effect of a smartphone app on weight change and metabolic outcomes in Asian adults with type 2 diabetes: a randomized controlled trial (Lim et al., 2021) (21)	JAMA Network Open	**Design:** Randomized Control Trial (RCT) **Sample:** Total sample 190 respondents, divided into 2 RCT groups (95 respondents per group), elderly with type 2 diabetes aged 21-75 years. **Variables:** Body weight, metabolic outcome (fasting glucose, HbA1c, blood pressure, cholesterol, triglyceride), nutrient intake, and physical activity. A smartphone-based lifestyle intervention. **Instruments:** Nutritional biochemistry, blood glucose, HbA1c, cholesterol, and triglyceride. **Analysis:** Parallel	The intervention group had a significant weight loss compared to the control group (mean/SD, -3.6/4.7kg vs -1.2/3.6kg). The intervention successfully reduced the HbA1c level of the elderly with 8% or more (mean/SD, -1.8%/1.4 vs -1%/1.4, $p<0.001$).

Continued in pag. S171…

…continuation Table 5. Article Analysis.

No.	Research Title & Citation	Journal Name	Research Method	Research Result
			blood glucose, HbA1c, cholesterol, and triglyceride. **Analysis:** Parallel multicenter 2-group RCT	
11.	Randomized controlled trial of mobile closed-loop control (Kovatchev et al., 2020) (17)	Diabetes Care	**Design:** Randomized Controlled Trial (RCT) **Sample:** 127 respondents with type 1 DM, aged 14-70 years, divided into mobile closed-loop control intervention group (n=65) and sensor augmented pump (SAP) therapy group (n=62). **Variables:** Glucose level, mobile closed-loop control (CLC). **Instrument:** mobile closed-loop control (CLC).	CGM (continuous glucose monitoring) below 3.9 mmol/L was 5% at baseline and 2.4% during follow-up in the CLC group vs. 4.7% and 4%, respectively, in the SAP group (mean difference -1.7%; p<0.0001). Mobile CLC is feasible and provides the advantages of using an integrated system.
12.	The effect of mHealth program on behavior modification and health outcomes among patients with diabetes: a randomized controlled trial study (Firdaus et al., 2023) (40)	Belitung Nursing Journal	**Design:** Randomized Controlled Trial (RCT) **Sample:** 58 elderly with uncontrolled DM (control and intervention groups). The intervention group was given the diabetic care app. **Variables** included foot care behavior, dietary behavior, and fasting blood glucose. The diabetic care app instrument consisted of a Malay-language translation of the Diabetic Foot Self-Care Behavior Scale (DFSBS) and a Dietary Behavior Questionnaire (DBQ). **Analysis:** Paired t-test, Wilcoxon signed rank test, MANCOVA, Mann-Whitney U test.	The pretest-posttest comparison in both groups revealed significant differences for foot care behavior ($p < 0.01$) and dietary behavior ($p < 0.01$), but not for fasting blood glucose levels. Between-group comparisons revealed significant differences only in foot care behavior ($p < 0.01$) and dietary behavior ($p < 0.01$).
13.	The International Diabetes Closed-Loop Study: Testing Artificial Pancreas Component Interoperability (Anderson et al., 2024) (18)	Diabetes Technology & Therapeutics	**Design:** Pilot study **Sample:** 43 elderly individuals with type 1 diabetes **Variables:** Mobile AP system (sensor and pump connectivity), glycemic control, usability, safety. **Instrument:** Mobile artificial pancreas (AP) system **Analysis:** exploratory	Mobile AP is a feasible intervention for T1D; its potential system configuration is well-defined, and studies are underway to ensure its widespread adoption.
14.	Use of a Meter with Color-Range Indicators and Mobile Diabetes Management App Improved Glycemic Control and Patient Satisfaction in an Underserved Hispanic Population: "Tu Salud" - a Randomized Controlled Partial Cross-Over Clinical Study (Katz et al., 2022) (6)	Diabetes Spectrum	**Design:** Randomized Controlled Trial (RCT) **Sample:** 112 elderly individuals with DM aged 18-70 years, intervention group (n=75), control group (n=37). **Variables:** One Touch (OT) Verio Flex glucose meter, the OT Reveal mobile app, and blood glucose. **Instruments:** Diabetes Treatment Satisfaction Questionnaire (DTSQC) and One Touch (OT) Verio Flex glucose meter and the OT Reveal mobile app.	The use of the OT Verio Flex meter and the OT Reveal mobile app in an underserved Hispanic population with predominantly type 2 diabetes, low numeracy, and feeling overwhelmed by diabetes, helped provide sustained improvement in glycemic control without an increase in hypoglycemic events. The subjects well received the meter and mobile app and may have important uses in similar low-number, low-literacy populations.
15.	Effect of Voluntary Participation on Mobile--Health Care in Diabetes Management: A Randomized Controlled Open-Label Trial (Lee et al., 2020) (41)	JMIR Publication	**Design:** Randomized Controlled Open-Label Trial **Sample:** 66 elderly with diabetes (≥19 years old), 27 in the control group, and 39 in the intervention group Variable: Application of Mobile Health care to diabetes management **Instrument:** Healthnote (mHealth) mobile app. **Analysis:** Independent t-test, paired t-test, and chi-square test.	A diabetes self-management application that includes self-monitoring of blood glucose, exercise, diet, and the speed of receiving notifications/educational messages. This study demonstrates that mHealth education affects self-management of diabetes in elderly individuals, including blood glucose levels.

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…continuation Table 5. Article Analysis.

No.	Research Title & Citation	Journal Name	Research Method	Research Result
16.	Efficacy of Personalized Diabetes Self Care Using an Electronic Medical Record-Integrated Mobile App in Patients with Type 2 Diabetes: 6-Month Randomized Controlled Trial (Lee et al., 2022) (42)	JMIR Publication	**Design:** Randomized Controlled Trial **Sample:** 269 diabetic elderly (≥50 years old) Independent: Diabetes self-care using Electronic Medical Record-Integrated application. **Instrument:** Mobile Diabetes Self-care (iCareD) and CareSens glucometer. This diabetes self-care application includes monitoring of blood glucose levels, diet, and physical activity. **Analysis:** Chi-square or Fisher's exact	Outcomes of the iCareD application to determine the difference in changes in HbA1c levels with fasting blood glucose levels. The mHealth intervention improves self-care and blood glucose control in elderly individuals with diabetes.
17.	Largest Amplitude of Glycemic Excursion calculated from Self-Monitoring Blood Glucose predicted the Episode of Nocturnal Asymptomatic Hypoglycemia Detected by Continuous Glucose Monitoring in Outpatients with Type 2 Diabetes (Wang et al., 2022) (43)	Frontiers in Endocrinology	**Design:** Randomized Controlled Trial **Sample:** 313 diabetic elderly (≥50 years old) **Variables:** Application of Continuous Glucose Monitoring to blood glucose level monitoring **Instrument:** Continuous Glucose Monitoring (iProTM2) was used in detecting low glucose levels, in this study, to monitor glucose fluctuations. OneTouch Ultra Vue is a blood glucose test device used for self-monitoring blood glucose levels. In this study, each participant used the glucometer for 72 hours. Participants were instructed to perform self-monitoring of blood glucose four times a day, before meals and before bedtime. **Analysis:** Chi-square test	Continuous glucose monitoring iProTM2 is an instrument designed to detect blood glucose levels and facilitate blood glucose monitoring in individuals with diabetes mellitus.
18.	Effectiveness of Lilly Connected Care Program (LCCP) App-Based Diabetes Education for Patients with Type 2 Diabetes Treated with Insulin: A Retrospective Real-World Study (Zhang et al., 2020) (5)	JMIR Publication	**Design:** Retrospective cohort study. **Sample:** 5,011 diabetic elderly (≥18 years old with an average sample age of ≥50 years old). **Variable:** use of Lilly Connected Care Program (LCCP) App on Blood Glucose Self-Monitoring Instrument: The Lilly Connected Care Program (LCCP) app is an educational course platform on diabetes management with 60 types of diabetes education courses. The education covers self-care behaviors in accordance with the American Diabetes Educators Association Standards of Care, including healthy eating, physical activity, blood glucose monitoring, medication management, and solutions to health problems. **Analysis:** ANOVA test	Diabetes education provided through the Lilly Connected Care Program (LCCP) app was effective in improving glycemic control in older adults with type 2 diabetes treated with insulin. This study also showed that self-monitoring of blood glucose increased in older adults who used the Lilly Connected Care Program (LCCP).
19.	The Use of Mobile Personal Health Records for Haemoglobin A1c Regulation in Patients with Diabetes: A Retrospective Observational Study (Seo et al., 2020) (20)	JMIR Publication	**Design:** Retrospective Observational Study **Sample:** 7,453 diabetic elderly (≥50 years old) **Variable:** use of Mobile Personal Health Records on Haemoglobin A1c levels in elderly type 2 diabetes mellitus. **Instrument:** My Chart in My Hand version 2.0 (MCMH 2.0) is a diabetes management application that provides functions for sugar input, a diabetes calendar, insulin treatment, food intake, and physical exercise. **Analysis**: t-squared	The data contained in this application includes health records, health calendar, health management, medication, and check-up reservations. Health management includes blood pressure, blood glucose levels, BMI, cardiovascular disease risk, and metabolic syndrome. This study showed that continuous diabetes users experienced a decrease in HbA1c levels of
20.	Design and Development of a Mobile-Based Self-Care Application for Patients with Type 2 Diabetes (Mehraeen et al., 2022) (44)	BMC Medical Informatics and Decision Making	**Design:** Design and Development study **Sample:** 32 diabetes self-care apps (No intervention on comparison elderly with 32 different apps) **Variable:** the effectiveness of Mobile-Based Self-Care on Self-care of elderly diabetes **Instrument:** The mobile-based self-care application (T2DM App) includes core functions such as teaching self-care instructions, controlling, managing, and self-monitoring the disease through reminders, receiving the number of exercise activities, alerts, and also preparing disease management process reports.	Apps include text message reminders, blood glucose monitoring, insulin dosing, educational messages, and metabolic management. This study improves the self-care of older adults with diabetes mellitus.

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..continuation Table 5. Article Analysis.

No.	Research Title & Citation	Journal Name	Research Method	Research Result
21.	Effect of a Mobile Phone-Based Glucose-Monitoring and Feedback System for Type 2 Diabetes Management in Multiple Primary Care Clinic Settings: A Cluster Randomized Controlled Trial (Yang et al., 2020) (19)	JMIR Publication	**Design:** Randomized Controlled Trial **Sample:** 150 (9 clinics) and 97 (4 clinics) (elderly >18 years old with an average age of ≥60 years old) **Variable:** Use of Mobile Phone-Based Glucose-Monitoring and Feedback System in the Management of Type 2 diabetes mellitus. **Instrument:** Mobile phone application (i-care smart K, Inssung information) and glucometer (GlucoNavi SD, GlucoLink 0.3, SD Biosensor Inc). **Analysis:** independent t-tests and Chi-Square tests	The blood glucose monitoring and feedback app improved blood glucose monitoring in older adults with diabetes mellitus. The app also reduced blood pressure and increased motivation and satisfaction among users.
22.	Diabetes Telemedicine Mediterranean Diet (DiaTeleMed) Study: study protocol for a fully remote randomized clinical trial evaluating personalized dietary management in individuals with type 2 diabetes (Berube et al., 2024) (45)	Trials Journal	**Design:** Randomized control trial. **Sample:** 255 diabetic elderly (21-80 years old) **Variable:** use of Diabetes Telemedicine Mediterranean Diet (DiaTeleMed) on dietary management of diabetic elderly **Instrument:** Diabetes Telemedicine Mediterranean Diet (DiaTeleMed) is a diabetes diet instrument that includes diet data recording, diet monitoring, education, and health behavior. Education in this telemedicine includes self-monitoring of blood glucose. **Analysis:** Primary and secondary analysis	This application includes diet recording, diet monitoring, counseling, education on type 2 diabetes mellitus, and self-monitoring of blood glucose levels.
23.	The effect of health quotient and time management skills on self-management behavior and glycemic control among individuals with type 2 diabetes mellitus (Chen et al., 2024) (46)	Frontiers in Public Health	**Design:** Randomized Controlled Trial **Sample:** 215 older adults with diabetes (≥18 years old; 40% of participants were ≥60 years old) **Variables:** health quotient and time management skills on self-management behavior and blood glucose control. **Instrument:** Health Quotient Scale (HQS), Diabetes Time-Management Questionnaire (DTMQ), Chinese version of Diabetes Self-Care Scale (DSCS), and Glucose. **Analysis:** Independent samples t-tests and Pearson correlation tests.	Health quotient and time management skills in older adults with type 2 diabetes act as catalysts for self-management behavior. Both influence HbA1c levels indirectly through self-management practices.
24.	Continuous Glucose Monitoring and Other Wearable Devices to Assess Hypoglycemia- s among Older Adult Outpatients with Diabetes Mellitus (Weiner et al., 2023) (4)	Thieme Journal	**Design:** Randomized Control Trial **Sample:** 10 diabetic elderly (aged 50-85 years) **Variable:** application of Continuous Glucose Monitoring on blood glucose changes **Instrument:** Continuous Glucose Monitoring (CGM) Abbott FreeStyle Libre Pro: a blood glucose monitor attached to the posterior arm. Connected to a smartphone via Abbott's FreeStyle software application. **Analysis:** Descriptive statistics and Research Electronic Data Capture (REDCap).	Continuous glucose monitoring performed over 2 weeks in older adults showed significant potential to improve diabetes self-management.
25.	GlucoTab-guided insulin therapy using insulin glargine U300 enables glycemic control with low risk of hypoglycemia in hospitalized patients with type 2 diabetes (37Aberer et al., 2019) (27)	Diabetes, Obesity, and Metabolism	**Design:** Randomized Controlled Trial **Sample:** 30 diabetic elderly (age ≥18 years, with an average age >60 years) **Variable:** use of GlucoTab in blood glucose control **Instrument:** GlucoTab is a blood glucose control device that is connected and integrated to health services through information systems. **Analysis:** one-tailed one-sample t-test	In this study, blood glucose levels improved during treatment with GlucoTab and insulin glargine U300 in 30 participants with diabetes mellitus. This illustrates that GlucoTab and insulin glargine U300 are effective for treating and monitoring glycemia in elderly individuals with diabetes.

DISCUSSION

The effectiveness of using mobile applications for self-monitoring blood glucose (SMBG) in older adults with type 2 diabetes is evident in their ability to improve glycemic control and facilitate independent disease management. The application enables patients to record their blood glucose levels automatically and integrates with monitoring devices, resulting in more accurate, consistent readings compared to manual recording. Various studies have shown that clinical effectiveness is reflected in decreased HbA1c, reduced glucose variability, and a lower risk of hypoglycemia, especially among patients who regularly use the application. Additionally, the application is practical for increasing monitoring frequency, improving adherence to treatment schedules, and facilitating evaluation by healthcare workers. The effectiveness is also evident in the app's role in providing education, reminders, and real-time feedback, which makes patients more aware of their condition and encourages them to make healthy behavioral changes. Thus, the effectiveness of the SMBG app covers medical aspects (clinical outcomes), behavioral changes, and treatment decision-making, which together support the successful management of diabetes in the elderly.

Evaluating the effectiveness of SMBG based on clinical outcomes

Decrease in HbA1c levels

The SMBG app is efficacious in improving glycemic management, as evidenced by a decrease in HbA1c levels (2,7,13-16). SMBG provides quick feedback on blood glucose levels, allowing patients to make prompt adjustments to their diet, exercise, and medication, thereby improving glycemic control and lowering HbA1c levels (17,18). Continuous use of SMBG has been linked to long-term improvements in HbA1c levels, as seen in a study in which HbA1c remained stable and even improved after 1.5 years of SMBG integration (19).

Improving glycemic control

The review results show that SMBG has been proven to improve glycemic control (5,6,16,20-22). SMBG is beneficial for assessing glycemic variability (23). This enables greater accuracy in therapeutic improvements. SMBG empowers patients by enhancing their knowledge and understanding of their illness, resulting in improved self-management and adherence to treatment recommendations (24,25).

Decreasing Frequency and Duration of Hypoglycemia

SMBG has been shown to reduce the frequency of hypoglycemia (6,7) and its duration. SMBG is essential for recognizing hypoglycemia and enabling rapid corrective action to prevent severe hypoglycemic crises (26). This is crucial for individuals who take insulin or oral hypoglycemic medications. By offering real-time data, SMBG enables patients and medical professionals to identify trends that may lead to hypoglycemia and take preventive action (26,27).

Evaluation of SMBG Effectiveness Based on Self-Care Behavior (DM Management)

Self-monitoring of Blood Glucose (SMBG) is an important component of the self-management of diabetes mellitus (DM). Through SMBG, patients can independently monitor their blood glucose levels, enabling them to adjust their diet, physical activity, and medication accordingly. However, the effectiveness of SMBG depends heavily on the patient's self-care behavior, and it can also serve as a transformative tool when linked to adaptive and proactive self-care behaviors. Self-monitoring of Blood Glucose (SMBG) is also one of the pillars in diabetes management. However, the effectiveness of SMBG is not determined solely by the frequency of measurements; it also depends on the patient's ability to understand, interpret, and respond to monitoring results (2,7,13-16).

Evaluating the effectiveness of SMBG in the context of DM patients' self-care behaviors, including patient involvement in self-management, adherence, knowledge, and decision-making based on blood glucose test results, and patients' understanding of SMBG.

Self-monitoring of blood glucose (SMBG). SMBG is the routine measurement of blood glucose levels in patients, with laboratory staff at the community health center checking their blood glucose. This examination aims to: 1) Evaluate short-term glucose control, 2) Help patients recognize fluctuations in blood glucose levels, 3) Provide a basis for decision-making (for example, insulin adjustment) Self-Care Behavior in the Self-Management of DM Patients According to the American Association of Diabetes Educators (AADE), there are seven key behaviors in diabetes self-care: Eating healthy 2) Being physically active 3)Blood glucose monitoring 4) Treatment 5) Problem-solving 6) Emotional handling 7) Risk understanding The evaluation of SMBG effectiveness based on self-care behavior can be conducted through quantitative and qualitative approaches. The components analyzed include: 1) Frequency and consistency of SMBG, 2) Understanding the monitoring results, 3) Intervention based on SMBG results, 4) Compliance with medical and non-medical interventions, and 5) Clinical outcomes (HbA1c, hypoglycemia, hyperglycemia).

Analysis of SMBG Effectiveness Based on Self-Care Behavior

The Use of SMBG Results in Decision Making

Self-monitoring of Blood Glucose (SMBG) plays a crucial role in the management of diabetes mellitus, particularly in controlling HbA1c levels. Research shows that SMBG, carried out consistently — namely, at least once per day in type 2 diabetes with insulin and three to four times per day in type 1 diabetes — can reduce HbA1c by 0.4 %-1.0 %. The effectiveness of SMBG increases when monitoring results are actively used in decision-making, such as adjusting insulin doses, preventing hypoglycemia, and managing diet and physical activity. Without adequate education, SMBG becomes a technical activity with little clinical impact (12) .

Proper SMBG implementation not only increases patients' awareness of their condition but also encourages self-reflection and corrective actions, such as portion reduction or increased physical activity when glucose levels are elevated. SMBG also contributes to the strengthening of long-term self-care behaviours, including dietary compliance, medication adherence, regular exercise, and increased engagement in medical consultations. Conceptually, SMBG includes a cognitive-reflective pro cess that involves understanding glucose results, interpreting fluctuation patterns, and taking appropriate actions based on these results (2).

Patients who understand and discuss SMBG results with healthcare professionals are better able to detect early hypoglycemia, adjust insulin doses, and reduce the risk of acute complications. Intensive education has been shown to improve adherence and interpretation skills, as well as support independent decision-making (28). Therefore, education programs should include technical (glucometer use and measurement time), interpretive (understanding results and management strategies), and problem-based (decision-making exercises through case studies) (29).

Patient compliance with SMBG is influenced by various factors, including family support, financial conditions, and assistance from healthcare workers (30). Patients who perform all aspects of self-care effectively, including diet, exercise, medication, SMBG, and problem-solving, exhibit significant clinical improvements, characterized by decreased complications and an enhanced quality of life (31). In addition to education, support systems such as regular evaluation by health professionals, assistance with government- or insurance-provided tools and strips, and the integration of digital technology are essential. The use of result recording applications and data connection to electronic medical records can improve the effectiveness of glucose monitoring (32). Active patient involvement is key. Patients need to take responsibility for their disease management. Self-motivation, training, and peer group support can increase commitment to SMBG. Families also play a role

in supporting monitoring schedules and lifestyle changes. However, SMBG implementation still faces barriers, including high costs, low health literacy, misinterpretation of results, and low motivation. Possible solutions include equipment subsidies, community-based continuing education programs, medical assistance, and psychosocial support approaches. With a holistic approach, SMBG can become an integral part of diabetes control, delivered in a self-directed, sustainable manner.

Patient experiences related to the effectiveness of SMBG

DM patients are satisfied with the various tools and applications used for SMBG. The satisfaction of DM patients is attributed to the ease of use of SMBG tools and applications, the measurement and automation of blood glucose recording, and the user-friendly design of the application for those with low literacy. Patients are satisfied with the effectiveness of smartphone applications in improving glycemic management (15). Elderly DM patients using a mobile application and cloud app system (Smart e-SMBG) for diabetes management showed a significant increase in satisfaction scores (33). In line with this, elderly individuals with DM reported positive experiences with CGM (Continuous Glucose Monitoring) (16). Patients also reported ease of use with the IBG-Star, a glucometer connected to a smartphone with automatic data storage (34). Interventions for continuous glucose monitoring, such as mobile closed-loop control (CLC) and mobile artificial pancreas (AP) systems, have been shown to be feasible (35-46). The use of meters with color range indicators and mobile diabetes management applications is well accepted by DM patients with low literacy characteristics (6). Patients also expressed satisfaction with the mobile phone application (Hicare Smart K, Insung Information) and the glucometer (GlucoNavii SD GlucoLink 0.3, SD Biosensor Inc.), which facilitates ease of blood glucose measurement and automated blood glucose recording (37). The results of the systematic review show a range of positive experiences with the SMBG app. However, if there is an error in the SMBG application, it can reduce patient trust in its use (2).

LIMITATION

Several studies included in this review have differences in terms of research design, sample size, and analysis methods used. These variations can lead to heterogeneity, making it challenging to synthesize data comprehensively and impacting the consistency of results. Differences in design can also lead to unequal quality of evidence, while varying sample sizes affect the generalizability of findings. Additionally, different analysis methods can yield varying interpretations of the same variables, so caution is warranted when drawing general conclusions from the results of this systematic review.

CONCLUSION

Based on various studies, the use of mobile applications for blood glucose self-monitoring in older adults with type 2 diabetes has been shown to have a positive impact on various aspects of disease management, though results have varied. Most studies have shown decreases in HbA1c levels, increases in the frequency of blood glucose monitoring, and improvements in self-care behaviors, including diet compliance, physical activity, and foot care. In addition, the application has also been shown to increase user satisfaction, motivation, and positive experiences in diabetes management. However, technical obstacles remain, and features need to be adjusted to make them more user-friendly for the elderly. Overall, these findings confirm that mobile applications have the potential to be effective as clinical and behavioral support tools for improving glycemic control, promoting health behaviors, and enhancing the experience for older adults with type 2 diabetes.

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